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Environmentally Responsible Product Assessments for the Automobiles Made in China

EVALUATION DU PRODUIT ENVIRONNEMENTALEMENT RESPONSABLE POUR LES AUTOMOBILES FABRIQUES EN CHINE

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Abstract: This article discusses a general assessment of how the environmental performance of the automobile has changed over the years. We performed an SLCA and used the AT&T matrix and Delphi-technique to compare a 1990s era automobile(made in china) to one from the 2000s of China. From the comparison, we calculated 5 life stages of automobile production include premanufacturing, product manufacture, product delivery, product use and recycling. The comparison shows moderate environmental stewardship during resource extraction, packaging. The ratings during manufacturing and refurbishment/ recycling/ disposal are both poor, and during customer use are abysmal though it have some improvement. The overall rating of 1990s is far below what might be desired. In contrast, the overall rating for the 2000s vehicle is much better than that of the earlier vehicle but still leaving plenty of room for improvement.
Key words: AT&T matrix, environment, LCA, SLCA, automobile

Résumé: Cet article entreprend une évaluation générale du fait que comment la performance environnementale de l'automobile a changé ces dernières années. Nous avons effectué un SLCA et utilisé la matrice de l'AT&T ainsi que le technique Delphi afin de comparer un automobile des années 1990 (fabriqué en Chine) avec un autre des années 2000. A travers la comparaison, nous avons calculé 5 étapes de la production de l'automobile : préfabrication, fabricarion du produit, livraison du produit, utilisation du produit, recyclage. La comparaison montre un management environnemental modéré pendant l'extraction et l'empaquetage des ressources. Les évaluations durant la fabrication et la reconstruction /recyclage/ élimination sont toutes misérables, et pendant la période d'utilisation par les clients elle apparaît épouvantable malgré des améliorations. L'évaluation générale des années 90 est loin de répondre à notre désir. Au contraire, celle des années 2000 est bien meilleure que la précédente, mais reste beaucoup à désirer.
Mots-Clés: matrice de l'AT&T, environnement, LCA, SLCA, automobile

1. INTRODUCTION

The automobile has been subject to numerous studies concerning its environmental load. As one can imagine, given the tens of thousands of parts, and the complexity of consumer behaviors, vehicle types, and driving conditions, this is an enormous task. Yet, in spite of all of this complexity the results have been quite consistent. By far the most important place to look for opportunities for environmental improvement is in the vehicle use stage. The automobile and its manufacture provide a widely known and widely studied example of how SLCA (streamlined life-cycle assessments) is accomplished in practice.[4] Automobiles have both manufacturing and in-use impacts on the environment ,in contrast to many other products such as furniture or interior hardware.[5] The greatest impacts result from the combustion of gasoline and the release of tailpipe emissions during the driving cycle. It is during this approximately 10 year period where the average vehicle, with a fuel efficiency of about 10 km/L (23.8 miles/gallon), burns about 14 metric tons of gasoline while traveling about 120,000 miles. Furthermore, due to the stoichiometry of the combustion process, this fuel consumption translates into some 40 metric tons of CO_2. When other aspects of the life cycle are included (the energy to make the fuel, etc.) and other greenhouse gases are converted to their CO_2 equivalent, the resulting equivalent CO_2 emissions over the life time of the vehicle are about 94 metric tons

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or 9.4 tons/year.[6]

However, there are other aspects of the product that affect the environment, such as the dissipative use of oil and other lubricants, the discarding of tires and other spent parts, and the ultimate retirement of the vehicle.

This article will discuss a general assessment of how the environmental performance of the automobile has changed over the years, we performed an SLCA to compare 1990s automobile(made in China) to one from the 2000s.

2. METHODOLOGY

2.1 The SLCA Matrix

The assessment system recommended here was developed by the authors in 1993 at AT&T. It has as its central feature a 5×5 matrix, the Environmentally Responsible Product Assessment Matrix. [7] One dimension of the matrix is life-cycle stage; an other is environmental concern (“Tab 1”). In use, the assessor studies the product designs to each element of the matrix an appropriate value. There is no a priori reason why the matrix element values must be continuous. Expert systems of various kinds often use data that are quantized: The values may be either binary (as in problem/no problem decision systems) or ordinal (as in a 1-10 severity ranking system). In the approach we recommend, the assessor assigns an integer rating from 0 (highest impact, a very negative evaluation) to 4 (lowest impact, an exemplary evaluation). In essence, what the assessor is doing is providing a figure of merit to represent the estimated result of the more formal LCA(life-cycle assessments) inventory analysis and impact analysis stages. She or he is guided in this task by experience, a design and manufacturing survey, appropriate checklists, and other information. The process is purposely qualitative and utilitarian, but does provide a numerical end point against which to measure improvement.

We used the Delphi-technique in favor of the nicety of the assessment. We have interviewed 18 experts who from the FAW company and JELY company.

Although the assignment of integer ratings seems quite subjective, experiments have been performed in which comparative assessments of products are made by several different industrial and environmental engineers. When provided with checklists and protocols as guidance, overall product ratings differ by less than about 15% among groups of several assessors.

Once an evaluation has been made for each matrix element, the overall Environmentally Responsible Product Rating (RERP) is computed as the sum of the matrix element values8:

$$R_{ERP} = \sum_i \sum_j M_{i,j} \quad (1)$$

Since there are 25 matrix elements, the maximum product rating is 100.

Designers who have never performed a product audit may wonder about the relevance of some of the life-stage-environmental concern pairs. To aid in perspective, “Tab 2” provides examples for each matrix element. The basis for some of these examples is that the industrial process is responsible (implicitly, if not explicitly) for the embedded impacts of the processing of raw materials that are used and for the projected impacts as the products are used, recycled, or discarded.

2.2 Target Plots

The matrix dispalys provide a useful overall assessment of a design, but a more succinct display of DfE (design for environmental) design attributes is provided by target plots, as shown in Fig.1. To construct the plots, the value of each element of the matrix is plotted at a specific angle.(For a 25-element matrix, the angle spacing is 360° /25=14.4°) A good product or process shows up as a series of dots bunched toward the center, as would occur on a rifle target in which each shot was aimed accurately. The plot makes it easy to single out points far removed from the bull’s-eye and to mark their topics out for to special attention by the design team. Furthermore, target plots for alternative designs of the same product permit quick comparisons of environmental responsibility. The product design team can then select among design options, and can consult the check-lists and protocols for information on improving individual matrix element ratings.[9]

3. ASSESSING GENERIC AUTOMOBILES OF YESTERDAY AND TODAY IN CHINA

We used the AT&T matrix and Delphi-technique to compare 1990s automobiles to that of the 2000s of China. Some of the relevant characteristics of the vehicles are given in “Tab 3”. In overview, the 1990s vehicle was substantially heavier, less fuel efficient, prone to greater dissipation of working fluids and exhaust gas pollutants, and had components such as

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[7] T.E Graedel B.R .Allenby, *Industrial ecology(Second Edition) ,2004.*

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tires that were less durable.

Premanufacturing, the first life stage, treats impacts on the environment as a consequence of the actions needed to extract materials from their natural reservoirs, transport them to processing facilities, purify or separate them by such operations, such as ore smelting and petroleum refining, and transport them to the manufacturing facility, where components are sourced from outside suppliers. This life stage also incorporates assessment of the impacts arising from component manufacture. The ratings assigned to this life stage of generic vehicles from each decade are given in Tab 4, where the two numbers in parentheses refer to the matrix element indices. The higher (that is, more favorable)ratings for the 2000s vehicle are mainly due to improvements in the environmental aspects of mining and smelting technologies, improved efficiency of the equipment and machinery used, and the increased use of recycled material.

The second life stage is product manufacture (see Tab 5). The basic automobile manufacturing process has changed little over the years, but much has been done to improve its environmental responsibility. One potentially high-impact area is the paint shop, where various chemicals may be used to clean the parts and volatile organic emissions can be generated during the painting process. There is now greater emphasis on treatment and recovery of waste water from the paint shop, and the switch from low-solids to high-solids has done much to reduce the amount of material emitted. With respect to material fabrication, there is currently better utilization of material (partially due to better analytical techniques for designing component parts) and a greater emphasis on reusing scraps and trimmings from the various fabrication processes. Finally, the productivity of the entire manufacturing process has been improved, substantially less energy and time being required to produce each automobile.

The environmental concerns at the third life stage, product delivery, include the manufacture of the packaging material, its transport to the manufacturing facility, residues generated during the packaging process, transportation of the fininshed and packaged product to the customer, and (where applicable) product installation (see Table 6). This aspect of the automobile’s life cycle is benign relative to the vast majority of products sold today, since automobliles are delivered with negligible packaging material. Nothetheless, some environmental burden is associated with trasport of a large, heavy product. The slightly higher rating for the 2000s automobile is due mainly to the better design of auto carriers and the increase in fuel efficiency of the transporters.

The fourth life stage ,product use, includes impacts from consumables (if any) that are expended during customer use (see Tab 7). Significant progress has been made in automobile efficiency and reliability, but automoblie use continues to have a very haigh negative impact on the environment. The increase in fuel efficiency and more effective conditioning of exhaust gases accounts for the 2000s automobile achieving higher ratings, but clearly there is still room for improvement.

The fifth life stage assessment includes impacts during product refurbishment and as a consequence of the eventual discarding of modules or components deemed impossible or too costly to recycle (see Table 8). Most modern automobiles are recycle (some 95% of those discarded enter the recycling system in most countries), and from these approximately 75% by weight is recovered as used parts or returned to the secondary metals market. Improvements in recovery technology have made it easier and more profitalbe to separate the automobile into its component materials.

4. CONCLUSIONS

In contrast to the 1990s, at least two aspects of modern automobile design and construction are better from the standpoint of their environmental implications. One is the increased diversity of materials used, mainly the increased use of plastics. The second aspect is the FEM (Finite-Element-Method), to decrease the weight of automobile, then, it will decrease the fuel using.

The completed matrices for the generic 1990s and 2000s automobile are illustrated in Tab 9. Examine first the values for the 1990s vehicle so far as life stages are concerned. The column at the far right of the table shows moderate environmental stewardship during resource extraction, packaging. The ratings during manufacturing and refurbishment/ recycling/ disposal are both poor, and during customer use are abysmal though it have some improvement. The overall rating of 51 is far below what might be desired. In contrast, the overall rating for the 2000s vehicle is 61, much better than that of the earlier vehicle but still leaving plenty of room for improvement. A more succinct display of DfE design attributes is provided by the target plots of “Fig. 1”

Tab 1 The Environmentally Responsible Product Assessment Matrix*

Environmental concern					
Life stage	Materials choice	Energy use	Solid residues	Liquid residues	Gaseous residues
Resource extraction	1,1	1,2	1,3	1,4	1,5
Product manufacture	2,1	2,2	2,3	2,4	2,5
Product delivery	3,1	3,2	3,3	3,4	3,5
Product use	4,1	4,2	4,3	4,4	4,5
Refurbishment,recycling,disposal	5,1	5,2	5,3	5,4	5,5

* The numerical entries in the table are matrix element indices

Tab 2 Examples of product Inventory concerns

	Environmental concern				
Life stage	Materials choice	Energy use	Solid residues	Liquid residues	Gaseous residues
Resource extraction	Use of only virgin materials	Extraction from ore	Slag production	Mine drainage	SO_2 from smelting
Product manufacture	Use of only virgin materials	Inefficient motors	Sprue,runner disposal	Toxic chemicals	CFC use
Product delivery	Toxic printing ink use	Energy loss in packing	Polystyrene packaging	Toxic printing ink use	Combustion emissions
Product use	Intentionally dissipated metals	Resistive heating	Solid consumables	Liquid consumables	Combustion emissions
Refurbishment ,recycling, disposal	Use of toxic organics	Energy loss in recycling	Nonrecyclable solids	Nonrecyclable liquids	HC1from incineration

Tab 3 Characteristics of Generic Automobiles

Characteristic	1990s automobile	2000s automobile
Materials（kg）		
Plastics	30	180
Aluminum	10	30
Copper	20	20
Lead	20	10
Zinc	25	18
Iron	192	180
Steels	1110	700
Glass	50	30
Rubber	80	80
Fluids	80	60
Other	83	82
Total weight（kg）	1700	1390（CA7230AT）
Fuel efficiency(km/gal）	15	27
Exhaust catalyst	No	Yes
Air conditioning	CFC-12	R134a

Tab 4 Premanufacturing ratings

Element designation	1990s auto	2000s auto
Materials choice (1,1)	3 (Few toxics are used, but most materials are not recycle)	3 (Few toxics are used, some materials are recycle)
Energy use (1,2)	2 (Virgin material shipping is energy intensive)	2 (Virgin material shipping is energy intensive)
Solid residue (1,3)	2 (Iron and copper ore mining generates substantial solid waste)	2(Metal mining generates waste)
Liquid residue (1,4)	2 (Resource extraction generates moderate amount of liquid waste)	3(Resource extraction generates a little of liquid waste)
Gas residue (1,5)	2 (Ore smelting generates significant amounts of gaseous waste)	3(Ore process generates moderate amounts of gaseous waste)

Tab 5 Product Manufacturing ratings

Element designation	1990s auto	2000s auto
Materials choice (2,1)	3 (CFCs used for metal parts cleaning)	3 (Good materials choices, except for lead solder waste)
Energy use (2,2)	2 (Energy use during manufacture is high)	2 (Energy use during manufacture is fairly high)
Solid residue (2,3)	2 (Lots of metal scrap and packaging scrap produced)	3 (Some metal scrap and packaging scrap produced)
Liquid residue (2,4)	2 (Substantial liquid residues from cleaning and painting)	3 (some liquid residues from cleaning and painting)
Gas residue (2,5)	2 (Amounts of volatile hydrocarbons emitted from paint shop)	3 (Amounts of volatile hydrocarbons emitted from paint shop,but it could be filtrate 85% venomousness air through the air decontaminate setting)

Tab 6 Product Delivering ratings

Element designation	1990s auto	2000s auto
Materials choice (3,1)	2 (Sparse，recyclable materials used during packaging and shipping)	3 (Sparse ,recyclable materials used during packaging and shipping)
Energy use (3,2)	1 (Over the road truck shipping is energy intensive)	2 (Long-distance land and sea shipping is energy intensive)
Solid residue (3,3)	1 (Small amounts of packaging during shipment could be further minimized)	2 (Some of packaging during shipment could be further minimized)
Liquid residue (3,4)	2 (Negligible amounts of liquids are generated by packaging and shipping)	2 (Negligible amounts of liquids are generated by packaging and shipping)
Gas residue (3,5)	1 (Substantial fluxes of greenhouse gases are produced during shipment)	2 (Moderate fluxes of greenhouse gases are produced during shipment)

Tab 7 Customer Use ratings

Element designation	1990s auto	2000s auto
Materials choice (4,1)	3 (Petroleum is a resource in limited supply)	3 (Substantial petroleum is a resource in limited supply)
Energy use (4,2)	3 (Fossil fuel energy use is very large)	2 (Fossil fuel energy use is very large)
Solid residue (4,3)	1 (Significant residues of tires, defective or obsolete)	2 (Modest residues of tires, defective or obsolete parts)
Liquid residue (4,4)	1 (Fluid systems are very leaky)	3 (Fluid systems are somewhat dissipative)
Gas residue (4,5)	3 (No exhaust gas scrubbing; high emissions)	2 (Co≤2.2g/km，Hc+No1≤0.5g/km)

Tab 8 Refurbishment/ Recycling/ Disposal ratings

Element designation	1990s auto	2000s auto
Materials choice (5,1)	3 (Most materials used are recyclable)	3 (Most materials recyclable, but sodium azide presents difficulty)
Energy use (5,2)	2 (Moderate energy use required to disassemble and recycle materials)	2 (Moderate energy use required to disassemble and recycle materials)
Solid residue (5,3)	2 (A number of components are difficult to recycle)	2 (some components are difficult to recycle)
Liquid residue (5,4)	3 (Liquid residues from recycling are minimal)	3 (Liquid residues from recycling are minimal)
Gas residue (5,5)	2 (Recycling involves some open burning of residues)	2 (Recycling involves some open burning of residues)

Tab 9 Environmentally Responsible Product Assessments for the generic 1990s and 2000s Automobiles

	Environmental Stressor					
Life Cycle Stage	**Materials Choice**	**Energy Use**	**Solid Residues**	**Liquid Residues**	**Gaseous Residues**	**Total**
Pre manufacture						
1990s	3	2	2	2	2	11/20
2000s	3	2	2	2	3	12/20
Product Manufacture						
1990s	3	2	2	2	2	11/20
2000s	3	2	2	2	3	12/20
Product Delivery						
1990s	2	1	1	2	1	7/20
2000s	3	2	2	2	3	12/20
Product Use						
1990s	3	3	1	1	3	11/20
2000s	3	2	2	3	3	13/20
Refurbishment,						
Recycling						
Disposal						
1990s	3	2	2	3	2	12/20
2000s	3	2	2	3	2	12/20
Total						
1990s	12/20	12/20	7/20	10/20	10/20	**51/100**
2000s	15/20	10/20	10/20	12/20	14/20	**61/100**

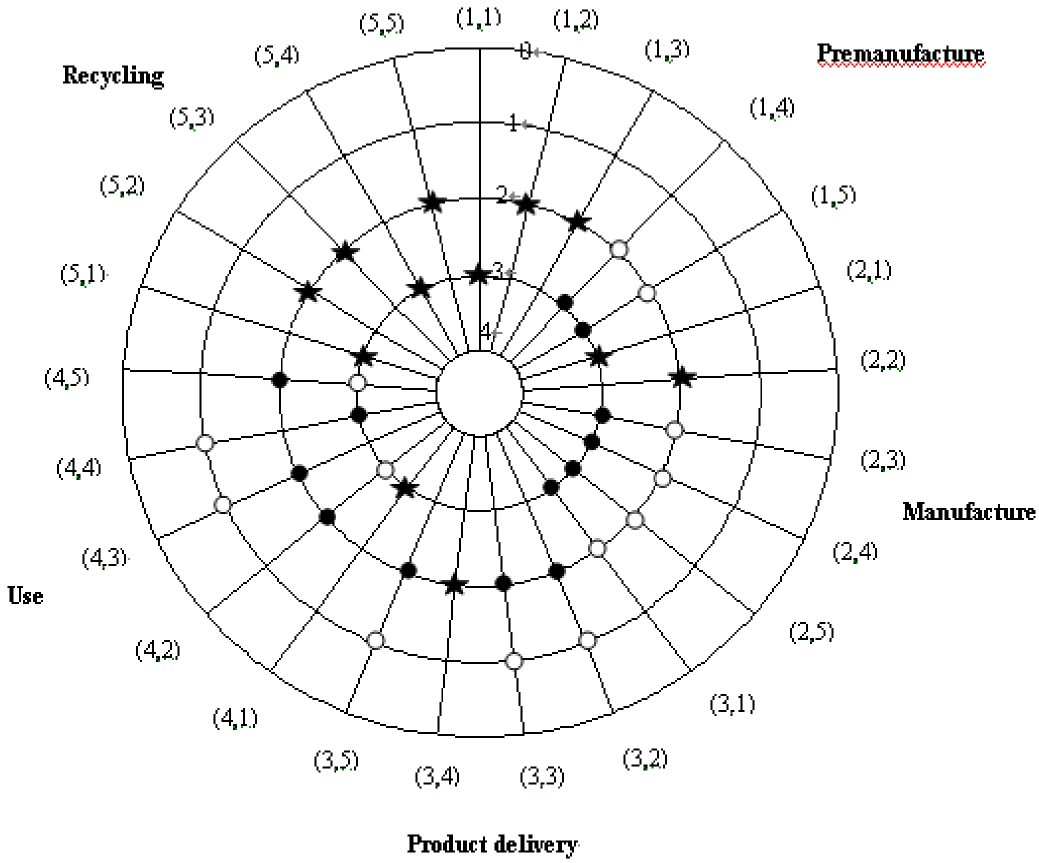

Fig. 1 Comparative target plots for the display of the enviromental impacts of the generic automobile of the 1990s and of the 2000s in china

Note: ● ~1990s rating; ★ ~2000s rating; ○ ~the rating of 1990s and 2000s

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